Summary of Hydrographic/CTD Observations Made Along Line P and at Station P: 1991-1999

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ABSTRACT

Minkley, B.G., and F.A. Whitney. 2001. Summary of hydrographic/CTD observations made along Line P and at Station P: 1991-1999. Can.Data Rep.Hydrogr.Ocean Sci.156: 45 p.

A summary of 30 missions which sampled part or all of Line P between January 1991 and December 1999 is provided. Plots of mission tracks show the areas surveyed, participants are listed, and types of sampling, inventoried. A review of sampling equipment outlines the conversion from 1.7 litre Niskin bottles mounted on 5/32-inch wire hydro wire to CTD/Rosette cast sampling using 10 litre bottles. Missions which supported programs for World Ocean Circulation Experiment and Joint Global Ocean Flux Studies are listed.

A previous report contained observations for the period January 1980 to December 1989 and is found in Canadian Data Report of Hydrography and Ocean Sciences No.136, by Tabata and Brown.

Key words: North Pacific Ocean, open-ocean time-series, hydrographic/CTD data.

RÉSUMÉ

Minkley, B.G., and F.A. Whitney. 2001. Summary of hydrographic/CTD observations made along Line P and at Station P: 1991-1999. Can. Data Rep. Hydrogr. Ocean Sci. 156: 45 p.

Ce rapport fourni un sommaire de 30 croisières océanographiques durant lesquelles la ligne P a été échantillonnée en tout ou en partie entre janvier 1991 et décembre 1999. Chaque sommaire comprend la région explorée représentée par la trajectoire du navire, la liste des participants, ainsi qu'un inventaire du type d'échantillons collectés. Une révision du matériel d'échantillonnage souligne la conversion de bouteilles Niskin de 1.7 litre montées sur un câble de 5/32" à des profils de CTD/Rosette utilisant des bouteilles de 10 litres. Les croisières faisant partie des programmes WOCE (World Ocean Circulation Experiment) et JGOFS (Joint Global Ocean Flux Studies) sont énumérées.

Un rapport précédant contenant les observations pour la période de janvier 1980 à décembre 1989 se trouve dans Can. Data Rep. Hydrogr. Ocean Sci. 136, par Tabata et Brown.

INTRODUCTION

The Line P program has been an important part of ocean research in Canada since the 1950s. Considerable effort has been expended to keep this monitoring program viable in the Northeast Pacific Ocean, the result being that the time series of measurements is proving extremely valuable in demonstrating the impact of climate change and variability on oceans. Early history and data from this program have been summarized by Tabata and Peart (1985). Dr. Tabata was largely responsible for ensuring the quality of the large temperature, oxygen and salinity data set up to 1990.

In the early 1990s, the Line P program came under the umbrella of the World Ocean Circulation Experiment (WOCE). Funding became available to upgrade virtually every measurement. Over a period of three years, the Institute of Ocean Sciences (IOS) switched from hydrographic bottle casts to CTD/rosette casts, with the result that CTD and water sampling became much better meshed, and depth measurements for samples improved. This was also the era that saw improved horizontal positioning due to the increased use and availability of the GPS for ship's navigation. With time, we added instruments to the CTD/rosette package so that we now routinely profile particle distribution to deep ocean, and light and fluorescence to 400 m. Data from 15 Line P surveys between 1991 and 1997 were submitted to the WOCE Hydrographic Program Office, and are available from http://oceanic.cms.udel.edu/woce/; ftp://nemo.ucsd.edu/woce/Data/Pacific/Repeat/PR6/.

Improvements were also made to routine chemical analyses. More analyses were done on fresh samples at sea than ever before. In part this was possible because the research vessel, CCGS *JOHN P TULLY*, has adequate lab space in which to set up analytical instruments. In addition to oxygen and nutrients, in the past decade we have measured CFCs, iron, total CO_2, alkalinity, pCO_2, chlorophyll and dimethyl sulfide at sea.

Line P also became a focus of activity under the Joint Global Ocean Flux Study program (JGOFS). The Canadian JGOFS program, from 1992 to 1997, decided to concentrate effort on understanding the controls of biological growth in the Gulf of Alaska. Great effort to solve this riddle came from the University of British Columbia (UBC) and other Canadian universities and international collaborators. A result of this work was the publication of a special volume of Deep Sea Research II (vol. 46, No. 11-12, 1999) which contains a review of the Line P program (Whitney and Freeland, 1999) and an additional 25 papers on biological, geochemical and physical processes of the NE Pacific. Core measurements from JGOFS studies are available from the Marine Environment Data Service, Fisheries and Oceans at http://www.meds-sdmm.dfo-mpo.gc.ca/.

The focus on processes in the Northeast Pacific during WOCE and JGOFS have spurred several important findings that relate climate change and variability to ocean productivity. Freeland *et al* (1998) have shown that the upper ocean mixed layer has been shoaling over the past 40 years, with the result that nutrient supply to phytoplankton is weaker. Between the 1970s and 1990s, Whitney and Freeland (1999) found an approximately 30% decline in the winter supply of nitrate to surface waters. Also, about 40% of the interannual variability in this supply appears to be modulated by El Nino – La Nina cycles (Whitney *et al*, 1998). We are now

confident that iron is a limiting nutrient in open waters in this area (Boyd et al, 1996) and still are uncertain about the interactions of light, temperature and nutrient supply in controlling plankton growth. Also unresolved is the understanding of how various nutrients are transported to the surface ocean.

Interest in open ocean research remains strong. The Alaskan Gyre region of the Northeast Pacific is a major habitat of Pacific salmon and a sizeable heat sink/source which moderates Canadian west coast weather. We foresee the Line P program continuing as an important contribution in understanding the impacts of climate variability on world oceans.

SHIPS AND PERSONNEL

The majority of the scientific personnel participating in these mission were from IOS. A few members have made 10 or more trips to Ocean Station Papa during this decade:

	Trips		*trips*
Ron Bellegay	12	Wendy Richardson	16
Reg Bigham	10	Marie Robert	14
John Love	11	Tim Soutar	21
Hugh Maclean, UBC	21	Frank Whitney	19
Bernard Minkley	23		

In addition to IOS staff, personnel from the following agencies participated:

Canadian Wildlife Service
Japanese scientists from both industry and universities
Memorial University, St. Johns, Newfoundland
McGill University
Pacific Biological Station, Nanaimo
Pacific Oceanological Institute of Russia
Princeton University
Third Institute of Oceanography of China
University of British Columbia
University of Rimouski
University of Southampton
University of Toronto
University of Victoria

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Whitney, F.A., C.S. Wong, and P.W. Boyd. 1998. Interannual Variability in Nitrate Supply to Surface Waters of the Northeast Pacific Ocean. Mar. Ecol. Prog. Ser. 170: 15-23.

Table 1. List of ships, dates, and personnel, 1991 to 1999

Mission	ship	start date	end date	master	area
91-03	Tully	19-Feb-91	11-March-91	John Anderson	Line P, Line Z, line R, lines MB and MA

CTD: Guildline 8715 SN 53501.

Ron	Bellegay	IOS	chief scientist
Beg	Bigham	IOS	
Gilles	Desmeules		
Bernard	Minkley	IOS	
Tim	Soutar	IOS	
Darren	Tuele	IOS	
Jinping	Wu	UBC	

91-08	Parizeau	28-Apr-91	10-May-91	John Campbell	line P, line R, line MA

CTD: Guildline SN 53501 and 58483

Sus	Tabata	IOS	chief scientist
Mary-Beth	Bérubé	IOS	
John	Love	IOS	
Bernard	Minkley	IOS	
Graeme	Quin	contractor	
Les	Spearing	IOS	
Jin Ping	Wu	UBC	

91-15	Endeavour	17-Oct-91	1-Nov-91	W. McMunagle	Line P, line Z

CTD: Guildline 8706 SN 43571 and 8715 SN 58483
Reversing thermometers used with 1.7 litre Niskin bottles.

Ron	Bellegay	IOS	chief scientist
Mike	Dempsey	contractor	
Hugh	Maclean	UBC	
Bernard	Minkley	IOS	
Robert	Mugo	UTC	
Ron	Perkin	IOS	
Tim	Soutar	IOS	
Les	Spearing	IOS	
Jinping	Wu	UBC	

92-01 Tully 03-Feb-92 14-Feb-92 John Anderson Line P, line R (partial)

CTD: Guildline 8706 SN 43501 and 8715 SN 58483

Frank	**Whitney**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Keith	Johnson	IOS	
Robert	Millar	co-op student	
Bernard	Minkley	IOS	
Tom	Moore	Guildline Instruments	
Wendy	Richardson	IOS	
Les	Spearing	IOS	
Clayton	Stark	co-op student	
Shu Lun	Wang	UBC	

92-06 Endeavour 26-Mar-92 13-April-91 W. McMunagle Line P line Z, line R, and line J

CTD: Guildline 8715 SN 53501 and 8715 SN 58483

Reversing thermometers used with 1.7 litre Niskin bottles.

Ron	**Perkin**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Reg	Bigham	IOS	
Bernard	Minkley	IOS	
Tim	Soutar	IOS	
Les	Spearing	IOS	
Jin Ping	Wu	UBC	

92-15 Tully 08-Sep-92 29-Sept-92 Paul Frost Line P, line Z, line R (partial)

CTD: Guildline SN 58483 and 59901 (testing only), Swann CTD winch

General Oceanics Rosette frame.

Reversing thermometers used for depths greater than 3000 m.

Frank	**Whitney**	**IOS**	**chief scientist**
Reg	Bigham	IOS	
Marty	Davelaar	IOS	
Nick	Hall-Patch	Co-op student	
John	Love	IOS	
Hugh	Maclean	UBC	
Brad	McKelvey	UBC	
Bernard	Minkley	IOS	
Marie	Robert	contractor	
Tim	Soutar	IOS	
Diana	Varela	UBC	

93-03 Tully 06-Mar-93 18-March-93 John Anderson Line P
CTD: Guildline SN 59901 and 58483, Lantec winch used for Rosette casts.
New and much larger A-frame on deck
1 ½ " diameter shock cords used to help eliminate ship motion from Rosette.
Reversing thermometers used for depths greater than 3000 m.

Ron	**Perkin**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Philip	Boyd	UBC	
Anna	Flak	Poland	
John	Love	IOS	
Hugh	Maclean	UBC	
Bernard	Minkley	IOS	
Helen	Nicolidakas	UBC	
Wendy	Richardson	IOS	
Marie	Robert	contractor	
Tim	Soutar	IOS	
Diana	Varela	UBC	
Frank	Whitney	IOS	

93-09 Tully 14-May-93 31-May-93 John Anderson Line P, line R, line J
CTD: Guildline SN 59901 and 58483, Lantec winch used for Rosette casts
1 ½ " diameter shock cords used to help eliminate ship motion from Rosette.
Strain gauge on wire to determine maximum loading of wire.

Ron	Bellegay	IOS	
Reg	Bigham	IOS	
Philip	Boyd	UBC	
Sean	Doherty	UBC	
Nick	Hall-Patch	Co-op student	
Hugh	Maclean	UBC	
Bernard	Minkley	IOS	
Marie	Robert	contractor	
Steven	Ruskey		
Tim	Soutar	IOS	
Diana	Verela	UBC	
Mark	Wen	UBC	
Frank	**Whitney**	**IOS**	**chief scientist**
Jin Ping	Wu	UBC	

94-01 Tully 07-Feb-94 18-Feb-94 John Anderson Line P (partial)
CTD: Guildline SN 59901, Lantec winch used for Rosette casts.
A-frame mounted heavy compensator system.

Ron	**Perkin**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Reg	Bigham	IOS	
Philip	Boyd	UBC	
Sean	Doherty	UBC	
Bill	Green	IOS	
John	Love	IOS	
Hugh	Maclean	UBC	
Bernard	Minkley	IOS	
Dario	Stucchi	IOS	
Diana	Varela	UBC	
Mark	Wen	UBC	
Frank	Whitney	IOS	

94-02 Tully 10-May-94 27-May-94 John Anderson Line P, R16, R12 and R8.
CTD: Guildline SN 59901 and 58483, Lantec winch
Training mission in Saanich Inlet and Haro Strait for the following personnel:
Mary Beth Bérubé, Robin Brown, Tracy Feeney, Howard Freeland, John Garrett, Bill Green, Rhiannon, Johnson, Tom Juhasz, Bernard Minkley , Taimi Mulder, Ron Perkin, Wendy Richardson, Dennis Simmott, Terry Sowden, Carol Steward, Neil Sutherland, Sarah Thornton, Linda White, Frank Whitney , Bob Wilson.
Most of these people departed the ship in Esquimalt harbour and the following personnel joined the ship for mission out to Ocean Station Papa:

Frank	**Whitney**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Reg	Bigham	IOS	
Philip	Boyd	UBC	
Marty	Davelaar	IOS	
Sean	Doherty	UBC	
Keith	Johnson	IOS	
John	Love	IOS	
Hugh	Maclean	UBC	
Bernard	Minkley	IOS	
Jim	Powlik	contractor	
Wendy	Richardson	IOS	
Marie	Robert	contractor	
Tim	Soutar	IOS	
Diana	Varela	UBC	
Mark	Wen	UBC	

94-03 Tully 06-Sep-94 9-Nov-94 John Anderson Line P, WOCE line P15N
CTD: Guildline SN 59901 and 58483, Lantec winch used.

John	Garrett	IOS chief scientist
Andrei	Andreev	POI, Vladivostak Russia
Ron	Bellegay	IOS
Mary-Beth	Bérubé	IOS
Reg	Bigham	IOS
Valerie	Knight	contractor
John	Love	IOS
Bernard	Minkley	IOS
Galina	Pavlova	POI, Vladivostak, Russia
Leo	Rebele	UBC
Marie	Robert	contractor
Tim	Soutar	IOS
Dario	Stucchi	IOS
Sarah	Thornton	UBC
Louise	Timmermans	UBC
Pavel	Tishchenko	POI, Vladivostak Russia
Linda	White	contractor
Frank	Whitney	IOS

95-01 Tully 07-Feb-95 23-Feb-95 Al Combs Line P
CTD: Guildline SN 59901 and 58483, Swann 329 winch used for rosette casts.

Frank	Whitney	IOS chief scientist
Reg	Bigham	IOS
Philip	Boyd	UBC
Tracy	Feeney	UBC
Robert	Goldblatt	UBC
John	Love	IOS
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Tim	Soutar	IOS

95-05 Tully 09-May-95 25-May-95 Al Coombs Line P, 130W grid
CTD: Guildline SN 59901 and 58483

Frank	Whitney	IOS chief scientist
John	Berges	UBC
Reg	Bigham	IOS
Philip	Boyd	UBC
Stuart	Brock	Co-op student
John	Love	IOS
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Kate	Read	
Wendy	Richardson	IOS
Tim	Soutar	IOS
Sarah	Thornton	UBC

95-12 Tully 22-Aug-95 13-Sept-95 Al Coombs Line P
CTD: Guildline SN 59901 and 58483

Philip	**Boyd**	**UBC**	**chief scientist**
Janet	Barwell-Clarke	contractor	
Ron	Bellegay	IOS	
Reg	Bigham	IOS	
John	Love	IOS	
Hugh	Maclean	UBC	
Wendy	Richardson	IOS	

96-01 Tully 20-Feb-96 8-March-96 John Anderson Line P
CTD: Guildline SN 59901 and 58483

Frank	**Whitney**	**IOS**	**chief scientist**
Ron	Bellegay	IOS	
Jim	Bishop	UVIC	
Philip	Boyd	UBC	
Stacey	Cooper	UVIC	
Ken	Crocker	MUN	
Robert	Goldblatt	UBC	
Nick	Hall-Patch	Co-op student	
Bernard	Minkley	IOS	
Todd	Mudge	UVIC	
Jennifer	Putland	MUN	
Wendy	Richardson	IOS	
Susanne	Roy	Rimouski U	
Nelson	Sherry	UBC	
Maureen	Soon	UBC	
Tim	Soutar	IOS	

96-09 Tully 07-May-96 30-May-96 John Anderson Line P, 129W grid
CTD: Guildline SN 59901 and 58483

Philip	**Boyd**	**UBC chief scientist**
Janet	Barwell-Clarke	contractor
Ron	Bellegay	IOS
Jim	Bishop	UVIC
Ken	Crocker	MUN
Robert	Goldblatt	UBC
John	Love	IOS
Hugh	Maclean	UBC
Paul	Mathews	MUN
Bernard	Minkley	IOS
Ken	Morgan	CWS
Todd	Mudge	UVIC
Jennifer	Putland	MUN
Wendy	Richardson	IOS
Nelson	Sherry	UBC
Robert	Schultz	UVIC
Maureen	Soon	UBC
Tim	Soutar	IOS
Delphine	Thibault	Rimouski U

96-18 Tully 12-Aug-96 6-Sept-96 John Anderson Line P, line R
CTD: Guildline SN 59901 and 58483

Frank	**Whitney**	**IOS chief scientist**
Doug	Anderson	IOS
Ron	Bellegay	IOS
Michael	Bentley	contractor
Philip	Boyd	UBC
Ken	Crocker	MUN
Edmund	Fok	IOS
Robert	Goldblatt	UBC
Julie	Granger	McGill U
Hugh	Maclean	UBC
Maite	Maldonado	McGill U
Paul	Matthews	MUN
Wendy	Richardson	IOS
Nelson	Sherry	UBC
Maureen	Soon	UTC
Tim	Soutar	IOS
Delphine	Thibault	Rimouski U

97-02 Tully 10-Feb-97 28-Feb-97 Kay Gimbel Line P
CTD: Seabird 0437

Frank	**Whitney**	**IOS chief scientist**
Laurent	Audaire	
Michael	Bentley	contractor
Jim	Bishop	UVIC
Philip	Boyd	UBC
Robert	Goldblatt	UBC
John	Love	IOS
Hugh	Maclean	UBC
Maite	Maldonado	McGill U
Paul	Matthews	MUN
Bernard	Minkley	IOS
Todd	Mudge	UVIC
Wendy	Richardson	IOS
Nelson	Sherry	UBC
Maureen	Soon	UBC
Tim	Soutar	IOS
Todd	Wood	UVIC
Jim	Zakreski	contractor

97-11 Tully 02-Jun-97 26-June-97 John Anderson Lines P, Z and AB
CTD: Seabird 0433

Philip	**Boyd**	**UBC chief scientist**
Doug	Anderson	IOS
Janet	Barwell-Clarke	contractor
Michael	Bentley	contractor
Robert	Goldblatt	UBC
Tara	Ivanochko	UBC
Keith	Johnson	IOS
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Wendy	Richardson	IOS
Nelson	Sherry	UBC
Maureen	Soon	UBC
Tim	Soutar	IOS
Nes	Sutherland	contractor
Darren	Tuele	IOS

97-15	Tully	25-Aug-97	17-Sept-97	Paul Frost	Lines P and MS (south of P)

CTD: Seabird 0437

Frank	**Whitney**	**IOS chief scientist**
Stuart	Brock	IOS
Lyle	Fairley	contractor
Kimio	Fukami	Japan
Takahiko	Inoue	Japan
Tara	Ivanochko	UBC
Keith	Johnson	IOS
Hiroshi	Kiyosawa	JAPAN
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Jun	Nishioka	JAPAN
Wendy	Richardson	IOS
Marie	Robert	contractor
Mark	Schmidt	U. Delaware
Tim	Soutar	IOS
Nes	Sutherland	contractor
Shigenobu	Takeda	Japan

97-37	Tully	20-Oct-97	30-Oct-97	Tom Hull	lines BP, G, D, line P (5 to 10), C, and B.

CTD: Seabird 0437

Doug	**Yelland**	**IOS chief scientist**
Mike	Bentley	contractor
Beth	Bornhold	UBC
Bridgett	Ferris	
Shannon	Harris	UBC
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Doug	Moore	IOS
Jennifer	Putland	UBC
Marie	Robert	contractor
Steve	Romaine	IOS
Diana	Varela	UBC

97-45	Laurier	01-Dec-97	4-Dec-97	Syd Webb	Line P (1-12)

CTD: Seabird 0437

Marie	Robert	contractor
Sheila	Toews	contractor

98-02	Laurier	18-Jan-98	21-Jan-98	Syd Webb	Line P (1-12), El Nino Watch

CTD: Seabird 0437

Marie	Robert	contractor
Sheila	Toews	contractor

98-03 Tully 16-Feb-98 6-March-98 Tom Hull Line P
CTD: Seabird 0437

Frank	**Whitney**	**IOS chief scientist**
Doug	Anderson	IOS
Michael	Bentley	contractor
David	Crawford	IOS
Tara	Ivanochko	UBC
Keith	Johnson	IOS
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Bernard	Minkley	IOS
Tom	Plath	volunteer
Wendy	Richardson	IOS
Marie	Robert	contractor
Nes	Sutherland	contractor
S.	Takeda	Japan
Sheila	Toews	contractor

98-13 Laurier 07-Apr-98 10-April-98 Norm Thomas Line P (1-12)
CTD: Seabird 0443

Doug	Anderson	IOS
Linda	White	contractor

98-15 Tully 01-Jun-98 26-June-98 Paul Frost Line P, line Z to Alaska, Bowie Seamount

CTD: Seabird 0443 and 0437

Ron	**Perkin**	**IOS chief scientist**
Doug	Anderson	IOS
Janet	Barwell-Clarke	IOS
Michael	Bentley	contractor
David	Crawford	UBC
Keith	Johnson	IOS
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Jun	Nishioka	UBC
Wendy	Richardson	IOS
Tim	Soutar	IOS
Nes	Sutherland	contract
Phillipe	Tortell	Princeton U
Darren	Tuele	IOS
Cathleen	Vestfalls	UBC

98-29 Tully 24-Aug-98 20-Sept-98 John Anderson Line P, eddy
CTD: Seabird 0443

Frank	**Whitney**	**IOS chief scientist**
Elaine	Baird	contractor
David	Crawford	UBC
Keith	Johnson	IOS
Hiroshi	Kiyosawa	Japan
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Adrian	Marchetti	IOS, student
Bernard	Minkley	IOS
Jennifer	Putland	contractor
Wendy	Richardson	IOS
Marie	Robert	contractor
Tim	Soutar	IOS
Nes	Sutherland	contractor

99-01 Tully 8-Feb-99 28-Feb-99 John Anderson Line P, eddy
CTD: Seabird 0443

Frank	**Whitney**	**IOS chief scientist**
Doug	Anderson	IOS
Michael	Bentley	contractor
David	Crawford	IOS
Keith	Johnson	IOS
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Jun	Nishioka	Japan
Wendy	Richardson	IOS
Marie	Robert	contractor
Tim	Soutar	IOS
Nes	Sutherland	contractor
Cathleen	Vestfals	UBC

99-10 Tully 31-May-99 24-June-99 Bill Noon Lines P1E and P

CTD: Seabird 0443

Ron	**Perkin**	**IOS chief scientist**
Michael	Arychuk	IOS
Elaine	Baird	contractor
Janet	Barwell-Clarke	IOS
Michael	Bentley	contractor
Vincent	Coronini	IOS, student
Mary	Davelaar	IOS
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Angelica	Pena	IOS
Melanie	Quenneville	contractor
Wendy	Richardson	IOS
Marie	Robert	contractor
Tim	Soutar	IOS
Nes	Sutherland	contractor
Darren	Tuele	IOS
Cathleen	Vestfals	UBC

99-21 Tully 23-Aug-99 14-Sept-99 Paul Frost Line P, line Z to Alaska, Bowie Seamount

CTD: Seabird 0437

Frank	**Whitney**	**IOS chief scientist**
Doug	Anderson	IOS
Michael	Arychuk	IOS
Michael	Bentley	contractor
Beth	Bornhold	IOS
David	Crawford	U. Southampton
Chantale	Freeman	UVIC
Phoebe	Lam	Princeton U
Michael	Lipsen	UBC
Hugh	Maclean	UBC
Jacqueline	O Connell	UBC
Jennifer	Putland	contractor
Marie	Robert	contractor
Tim	Soutar	IOS
Philippe	Tortell	Princeton U

Table 2. Types of samples taken on each mission.

mission	Start date	ship	Sal	oxy	nut	NH_4	Chl	POC	DON	TCO_2	Alk	pCO_2	CFCs	Fe	^{13}C	^{18}O	DMS
91-03	19-Feb-91	T	X	X	X(f)			X		X	X						
91-08	28-Apr-91	P	X	X	X(f)												
91-15	17-Oct-91	E	X	X	X(f)												
92-01	03-Feb-92	T	X	X	X			X		X			X				
92-06	26-Mar-92	E	X	X	X			X									
92-15	08-Sep-92	T	X	X	X			X		X							
93-03	06-Mar-93	T	X	X	X			X		X			X		X		
93-09	14-May-93	T	X	X	X			X		X					X		
94-01	07-Feb-94	T	X	X	X												
94-02	10-May-94	T	X	X	X			X		X	X	X	X				
94-03	06-Sep-94	T	X	X	X					X	X		X		X		
95-01	07-Feb-95	T	X	X	X			X							X		
95-05	09-May-95	T	X	X	X		X	X		X		X	X		X		
95-12	22-Aug-95	T	X	X	X			X				X			X		
96-01	20-Feb-96	T	X	X	X		X	X	X	X	X	X			X	X	X
96-09	07-May-96	T	X	X	X		X	X	X	X	X	X			X	X	X
96-18	12-Aug-96	T	X	X	X	X	X	X	X	X	X	X			X	X	X
97-02	10-Feb-97	T	X	X	X	X	X		X	X	X	X			X	X	
97-11	02-Jun-97	T	X	X	X	X	X	X	X	X	X	X		X	X	X	X
97-15	25-Aug-97	T	X	X	X	X	X	X	X	X	X	X		X	X	X	X
97-37	20-Oct-97	T	X	X	X(f)	X	X										
97-45	01-Dec-97	L															
98-02	18-Jan-98	L	X	-	X(f)												
98-03	16-Feb-98	T	X	X	X		X	X	X			X		X	X	X	X
98-13	07-Apr-98	L	X	-	X(f)												
98-15	01-Jun-98	T	X	X	X	X	X	X		X	X	X		X	X	X	X
98-29	24-Aug-98	T	X	X	X	X	X	X	X	X	X		X	X		X	X
99-01	08-Feb-99	T	X	X	X		X	X		X	X	X	X	X	X	X	X
99-10	31-May-99	T	X	X	X	X	X	X		X	X	X	X		X		X
99-21	23-Aug-99	T	X	X	X	X		X		X	X	X	X	X	X	X	

Abbreviations:

T	*CCGS John P Tully*	E	*CNAV Endeavour*
P	*CCS Parizeau*	L	*CCGS Sir Wilfrid Laurier*
sal	Salinity	TCO_2	Total carbon dioxide
oxy	dissolved oxygen	Alk	Alkalinity
nut	nutrients, Si, NO_3,PO_4 (f = frozen)	pCO_2	partial pressure of CO_2 in water
NH_4	Ammonium	CFCs	Chlorofluorocarbons
chl	Chlorophyll	Fe	Iron
POC	Particulate Organic Carbon (+ N)	^{13}C	Carbon 12/13 ratio in TCO_2
DON	Dissolved Organic Nitrogen	^{18}O	Oxygen 16/18 ratio in water
DMS	dimethyl sulphide	X(f)	Nutrient samples frozen

WATER SAMPLING EQUIPMENT

Reversing Thermometers

Deep sea reversing thermometers had been used on all missions up to 92-01 to obtain water temperatures. These thermometers were mounted on 1.7 litre Niskin bottles which were clamped to 5/32 inch diameter hydro wire (Seale construction, right regular lay, improved plough steel, galvanized, torque-balanced). The Niskin bottles collected water for oxygen and salinity analyses. Two protected and one unprotected thermometer was mounted in each bottle. In September 1992 we started using a General Oceanic Rosette frame with 10 litre Niskin bottles. Reversing thermometers were not used with this Rosette. For pressures greater than 3000 dbars (maximum depth of CTD) a bottle cast was done using 1.7-litre bottles fitted with reversing thermometers. After March 1993 reversing thermometers were no longer required to obtain temperatures, as an improved pressure sensor on the CTD allowed profiles to reach the ocean bottom.

CTD's used during years 1991 to 1999

A digital CTD made by Guildline Instruments of Smith Falls, Ontario was used for missions 91-03 to 92-15. Digital CTD model number 8715, serial numbers 53501 and 58483 have the following specifications:

Parameter	Accuracy	Resolution	Stability
Conductivity	±.005 psu	.001 psu	.002 psu/6 month
Temperature	±.005°	.001°	.002/30 days
Pressure	±.15%	.15 % FS	FS = 3000 dbars

In September 1992, a Guildline CTD, model 8737 (WOCE) serial number 59901 was purchased to allow us to meet World Ocean Circulation Study (WOCE) requirements for CTD observations. During mission 92-15, the high precision Guildline CTD was tested. This new system has the following specifications:

Parameter	Accuracy	Resolution	Response
Conductivity	±.002 psu	.00006 psu	< 50 ms
Temperature	±.002°C	.0004°C	< 50 ms
Pressure	±2 dbars	.3 dbars	< 1 ms

Accuracy specified is for 30 days and includes linearity, resolution, hysteresis, temperature and calibration uncertainty relative to national standards.

During years 1993 to1996, the WOCE CTD and CTD 58483 were used. Due to difficulties with the temperature sensors of these CTD's, a replacement system was purchased from Seabird Electronics, Seattle, Washington, USA. This system was a model SBE 11 *plus* deckunit, model SBE 911 *plus* CTD, and SBE Carousel water sampler model 32 for 24 bottles. The CTD has the following specifications:

Parameter	Accuracy	Resolution	Stability
Conductivity	±.003 psu	.0004 psu	.0003 psu/month
Temperature	±.001°	.0002°	.0002°/month
Pressure	±.015%	.001 % FS	.0015% full scale

Rosette

Prior to 1997, a rosette frame made by General Oceanics was used (Figure 2). This unit had a diameter of 152.4 cm and area of 18,200 cm^2, and could hold 24 ten-litre Niskin bottles. With 136 kg's of lead added to assist the frame to "fall", this unit required an additional 90 kg's of weight on a bridle suspended beneath the frame to stop it from tilting. The tilt angle was measured by two tilt sensors mounted on the rosette frame, and the signal feed into the CTD for logging. With no bridle on the Rosette frame, tilt angles greater than 45 degrees were measured. The 90 kg lead weight reduced tilt to a few degrees.

A more compact rosette frame but still holding 24 bottles, modelled on a unit designed by Pacific Marine Environmental Laboratory (PMEL), Seattle, Washington, USA, was built in June 1999 (Figure 1). This unit has a diameter of 121.9 cm, an area of 11,700 cm^2 and a height of 183 cm.

Water samplers from Ocean Test Equipment and from General Oceanics have both been used on these rosettes. In recent years, nylon coated steel springs have been used to close bottles instead of 11mm latex tubing. These springs are a good choice for relatively clean sampling and minimal Freon contamination. Sensors added to the Seabird CTD include transmissometers, fluorometers, an underwater light sensor, and a pH probe. Sea-bird CTD's make the addition of other sensors simple. In addition an independent 12 kHz pinger was used to detect the proximity of the CTD/rosette package to the bottom.

Heave Compensation:

On missions 93-03 and 93-09, a load accumulating system using Endeco 1" diameter shock-cords was used to decrease cable loading due to ships motion from the CTD/rosette package. This system consisted of:

1. three doubled 1" shock-cords spliced to a 1" square braid rope
2. A 1.5" double braid nylon pennant, longer than the shock-cords, all attached at both ends, by 4.25T shackles, to steel yokes.
3. One end is anchored to a load cell, a pennant from the outer end passes through a block and the pennant suspends the block through which the CTD/rosette is lowered.

In shallow depths the shock-cord acts as a spring to reduce motion on the rosette, at greater depths the shock-cord is at full stretch and the 1.5" double braid nylon pennant also carries the load. For safety reasons this system of heavy compensation was discontinued and replaced in September of 1993, with a pneumatic heave compensator installed on the large A-frame on the stern of the CCGS JOHN P. TULLY (figure 3).

The heave compensator consists of a double-ended air cylinder with double rope sheaves mounted on each rod end. Two equal lengths of wire rope are attached to fixed points on the underside of the cylinder. Each rope passes over one sheave at each end of the cylinder then through a swinging deflector sheave block and is terminated on the travelling Tri-plate block. When the load on the Tri-plate block increases (due to line tension), the trapped air pressure in the cylinder no longer fully supports the load and the cylinder compresses until a load/pressure equilibrium is again established. A decrease in line load similarly causes the cylinder to extend raising the Tri-plate. The trapped air is also contained in expansion chambers located adjacent to the cylinder. One chamber is permanently open to the cylinder charge pressure. When only the expansion chamber is in use, the compensator provides a "stiff" system. (A relatively large change in line tension is required to fully stroke the cylinder.) When the second larger expansion chamber is also utilized the compensator provides a "soft" system. (a much smaller change in line tension is required to stroke the cylinder.) The rod ends of the cylinder are connected to a

low pressure (approximately 5 psi.) expansion chamber to ensure that the cylinder does not suck in any moist air when it is being compressed. The large expansion chamber is always connected to the cylinder main charge pressure via a small orifice. This ensures that the large chamber slowly follows the system pressure and there will not be any major change of pressure and Tri-plate position when the expansion chamber is engaged.

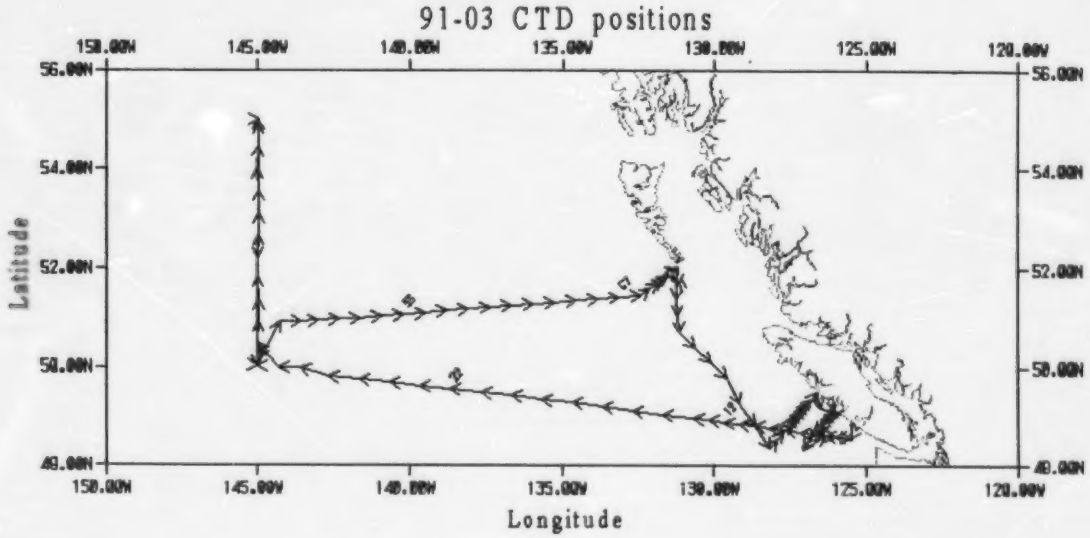
This system has been used on missions since 1994 to diminished cable loading during CTD/rosette casts. Also used on missions 93-03 and 93-09 was a cable tensiomcter to measure maximum cable loading. Tension measurements were in the range of 1360 to 1812 kilograms, but did on occasion exceed 2265 kilograms when the Rosette was started back up after reaching maximum depth (4200 metres) or the ship manoeuvred to correct the wire angle.

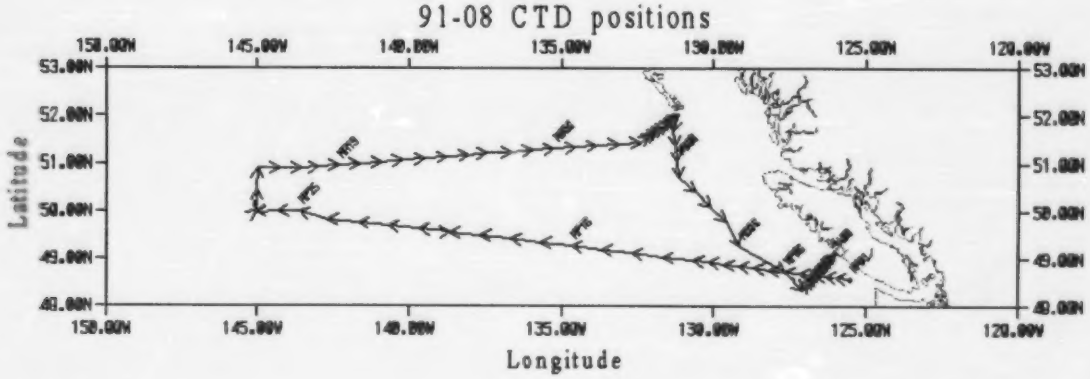
Table 3 of JGOFS and WOCE designated missions.

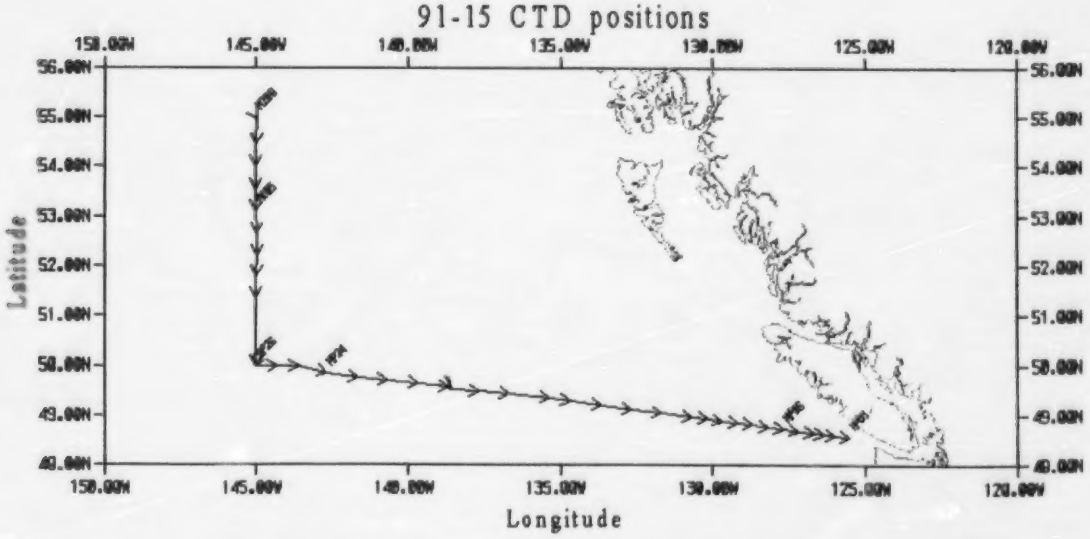
JGOFS = Joint Global Ocean Flux Study, WOCE = World Ocean Circulation Experiment

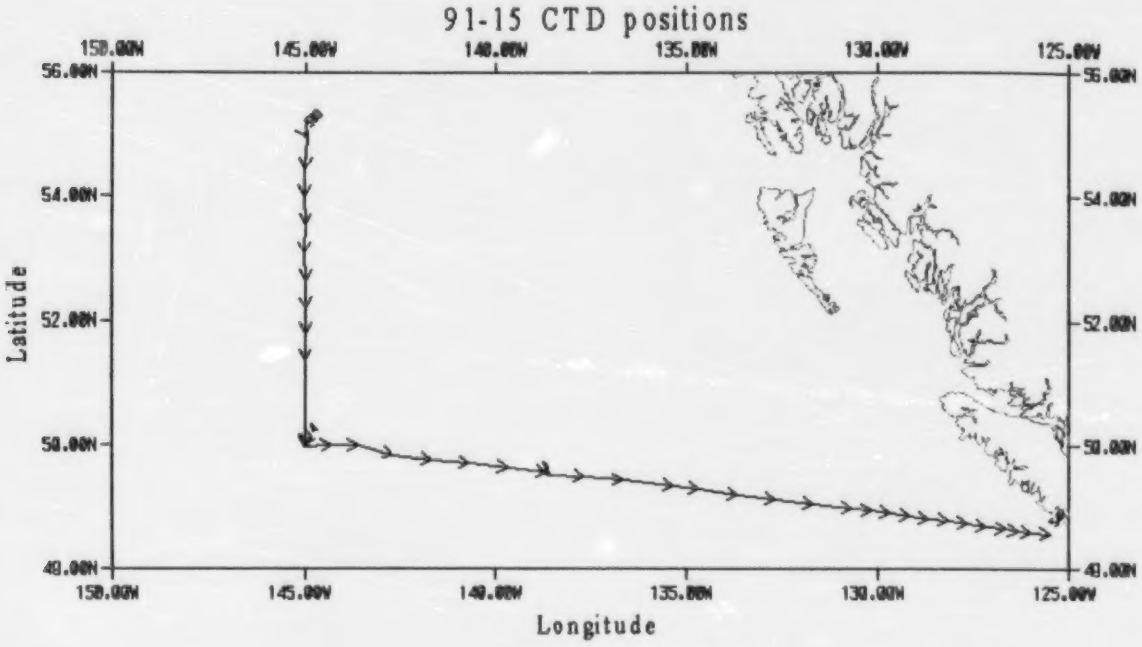
Mission	JGOFS	WOCE	Comments
91-03			
91-08			
91-15		X	First WOCE survey on line PR6 (line P)
92-01		X	
92-06		X	
92-15	X	X	First Canadian JGOFS mission
93-03	X	X	
93-09	X	X	
94-01	X	X	
94-02	X	X	
94-03		X	Line P and P15N (down 165°W)
95-01	X	X	
95-05	X	X	
95-12	X	X	
96-01	X	X	
96-09	X	X	
96-18	X	X	
97-02	X	X	Last WOCE repeat hydrographic line
97-11	X		Last JGOFS mission on line P
97-15			First attempt to deploy open ocean enclosures
97-37			GLOBEC mission
97-45			El Nino Watch
98-02			El Nino Watch
98-03			
98-13			El Nino Watch
98-15			
98-29			First eddy survey
99-01			
99-10			
99-21			

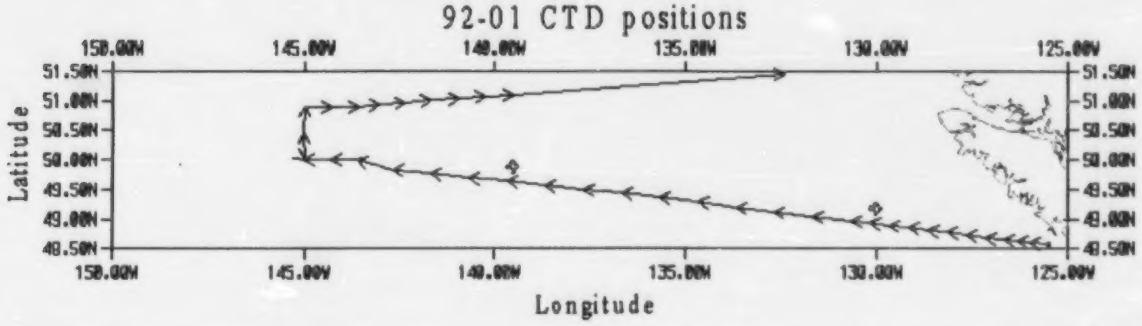
PLOTS OF CTD LOCATIONS FOR MISSIONS DONE 1991 TO 1999

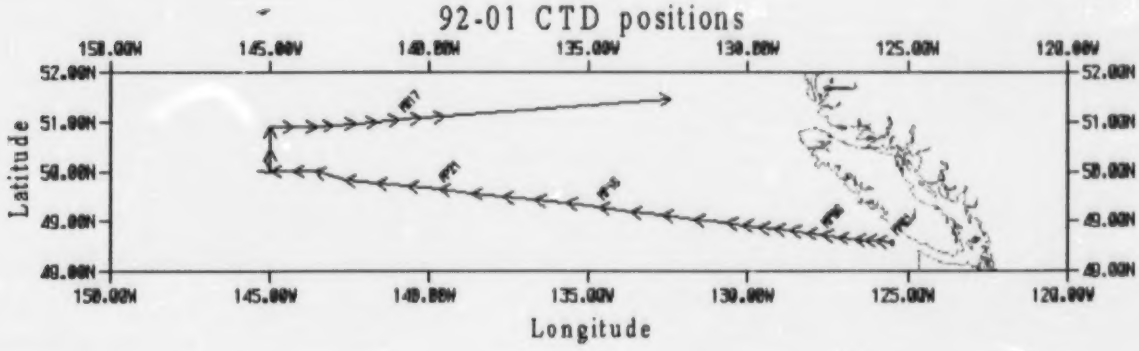


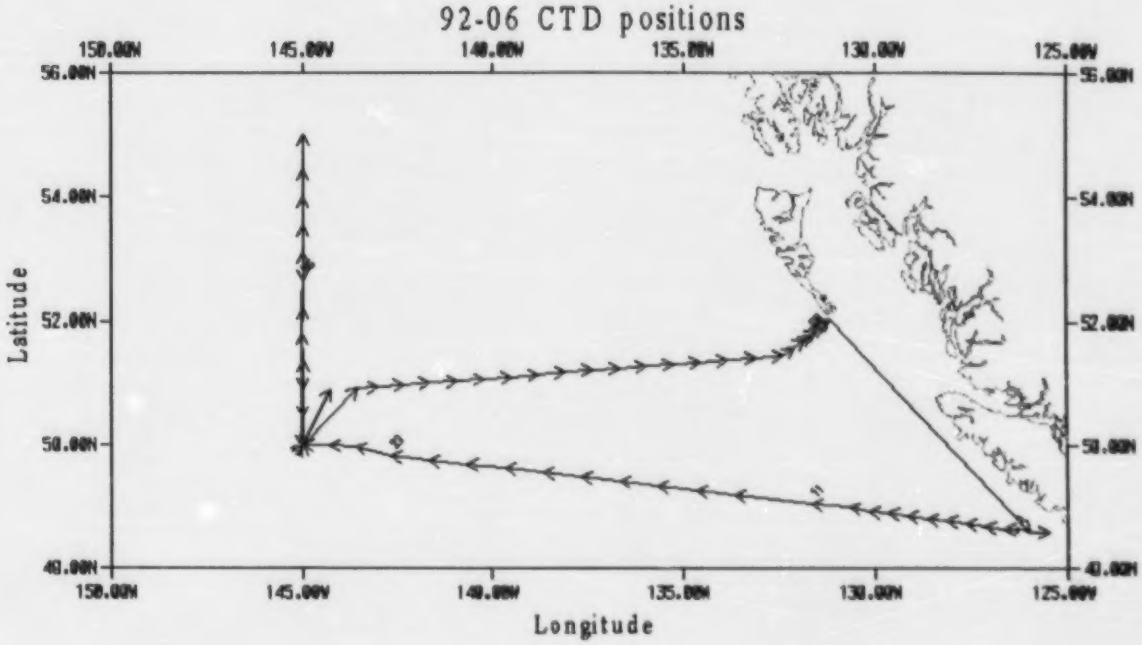


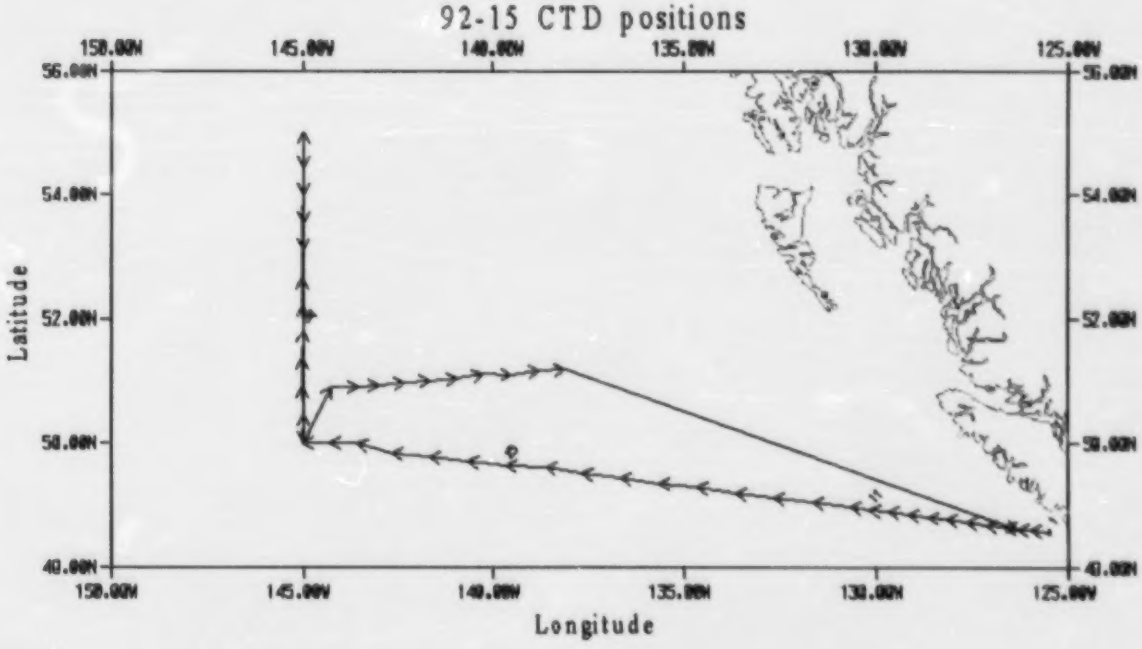



91-15 CTD positions
Latitude
Longitude


92-01 CTD positions
Latitude
Longitude


92-01 CTD positions
Latitude
Longitude


92-06 CTD positions
150.00W
145.00W
140.00W
135.00W
130.00W
125.00W
56.00N
54.00N
52.00N
50.00N
48.00N
Latitude
Longitude


92-15 CTD positions
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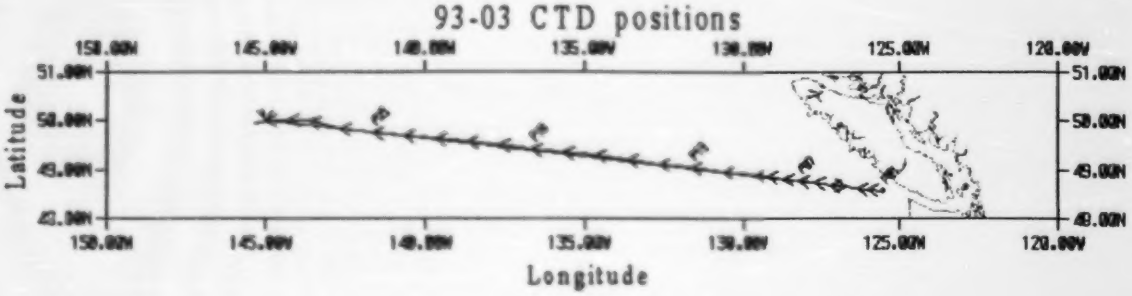
145.00W
140.00W
135.00W
130.00W
125.00W
56.00N
54.00N
52.00N
50.00N
48.00N
Latitude
Longitude


93-03 CTD positions
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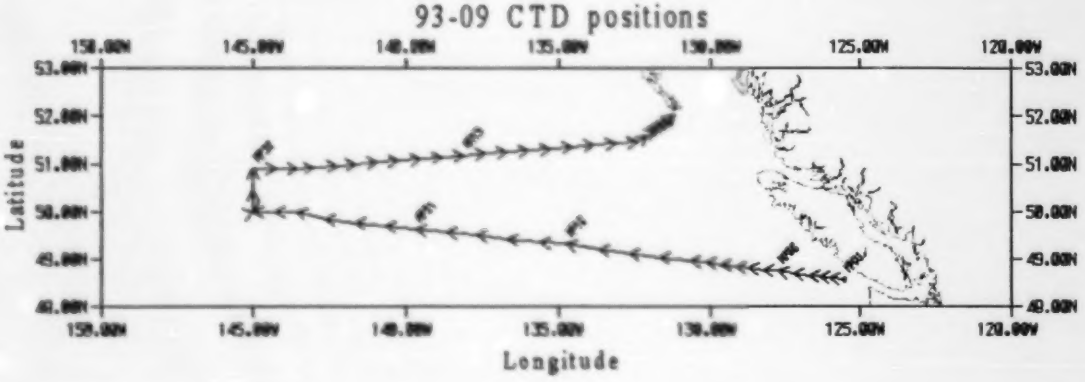
Longitude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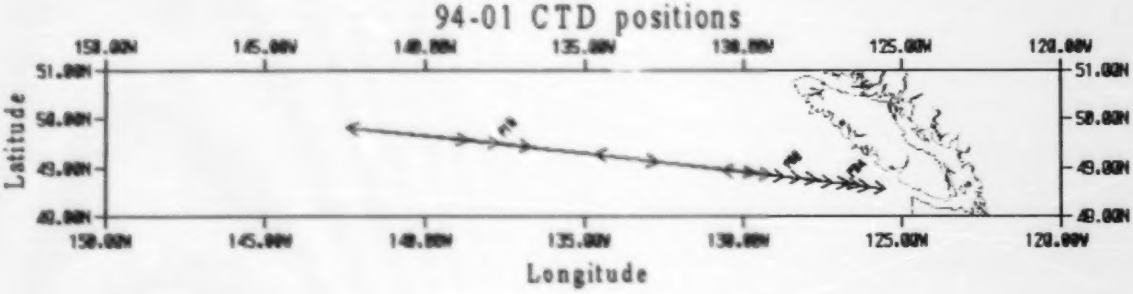
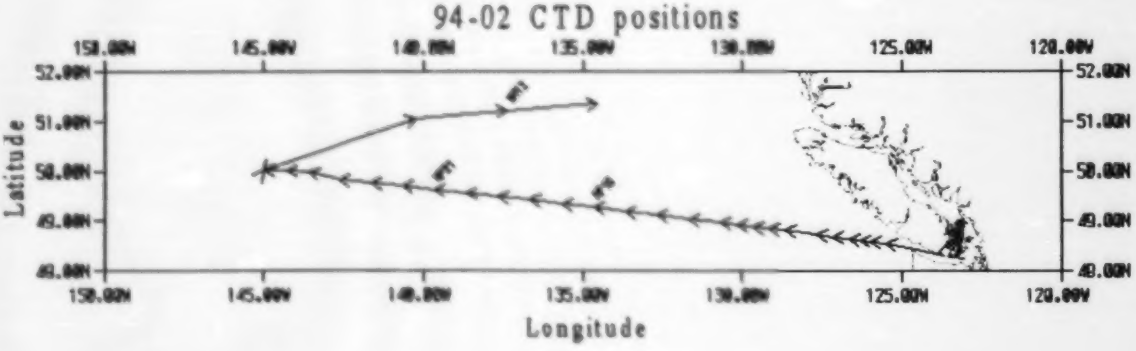
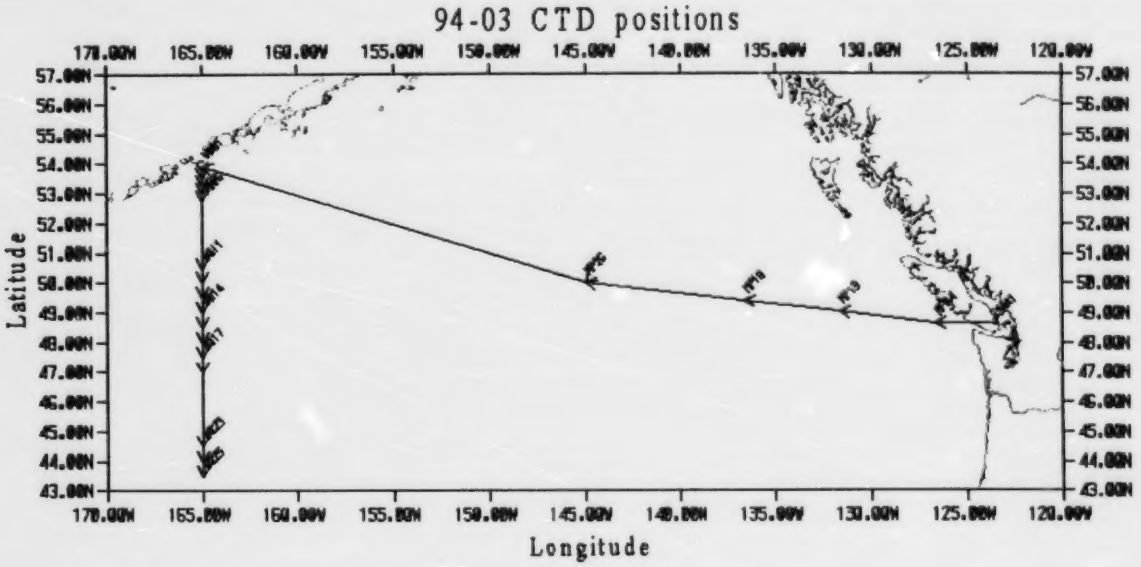
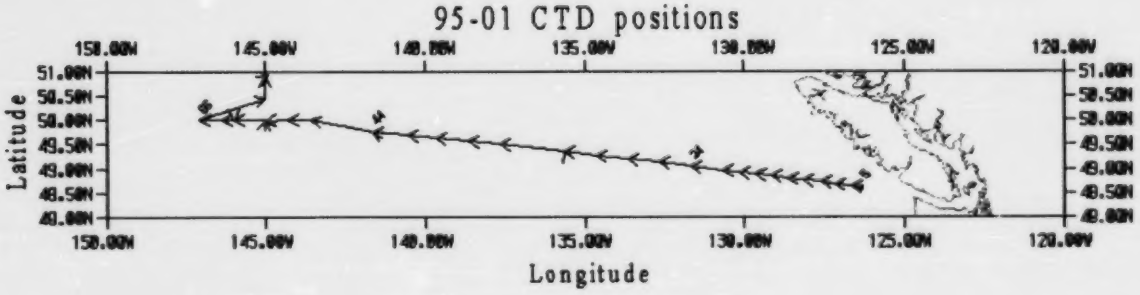
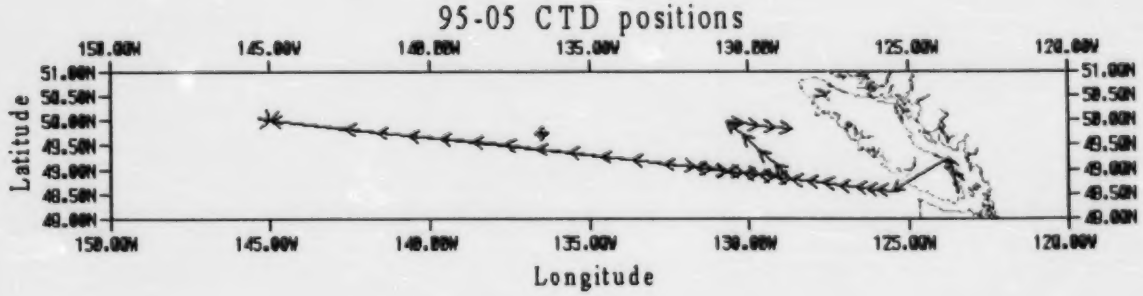
Longitude


94-01 CTD positions
Latitude
Longitude


94-02 CTD positions
Latitude
Longitude


94-03 CTD positions
Latitude
Longitude


95-01 CTD positions
Latitude
Longitude


95-05 CTD positions
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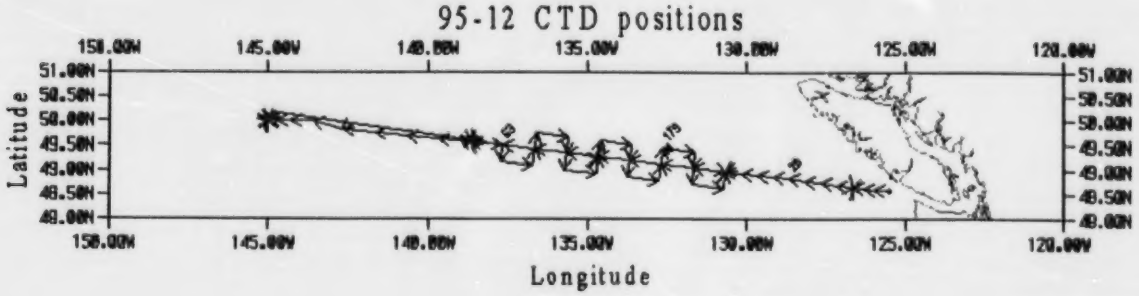
Longitude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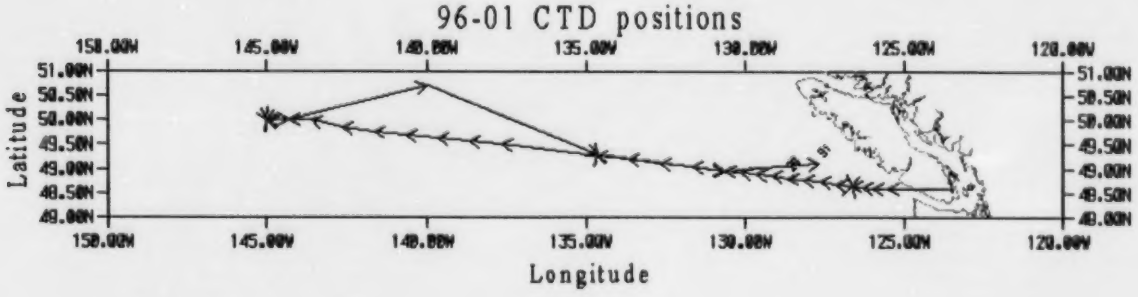
Longitude


96-01 CTD positions
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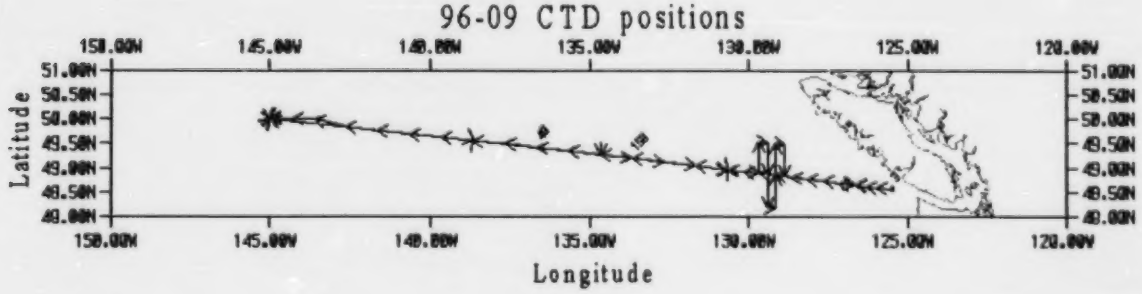
Longitude


96-09 CTD positions
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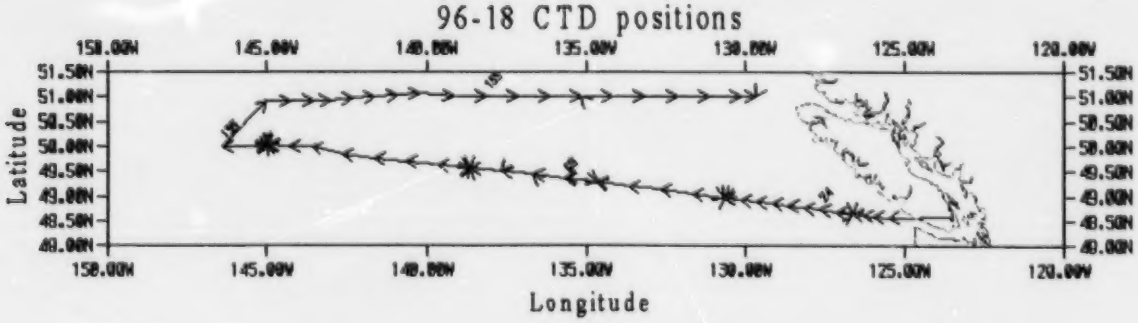
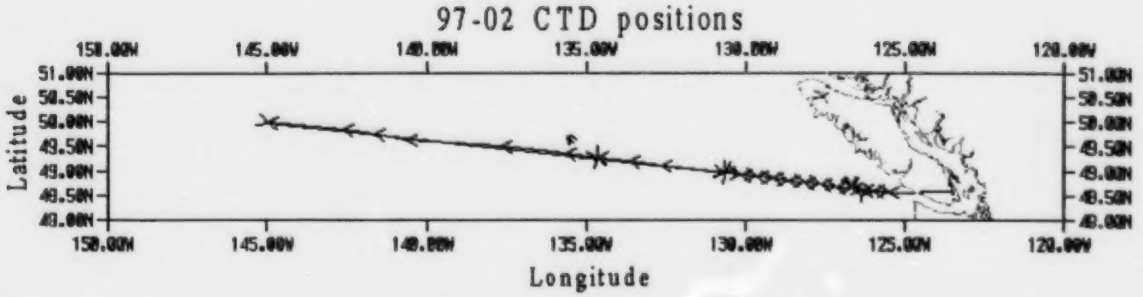
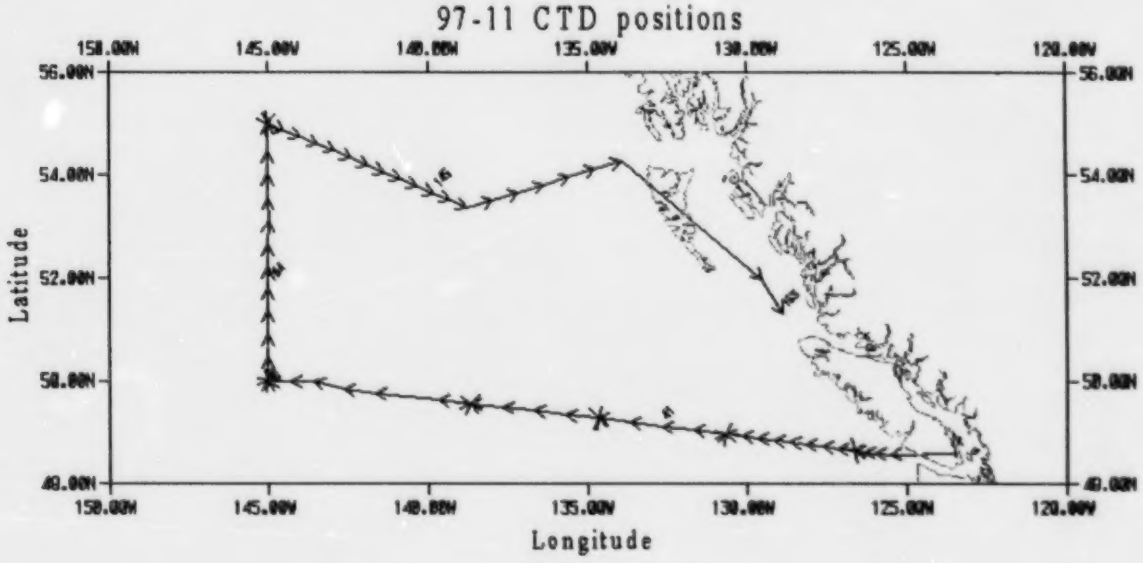
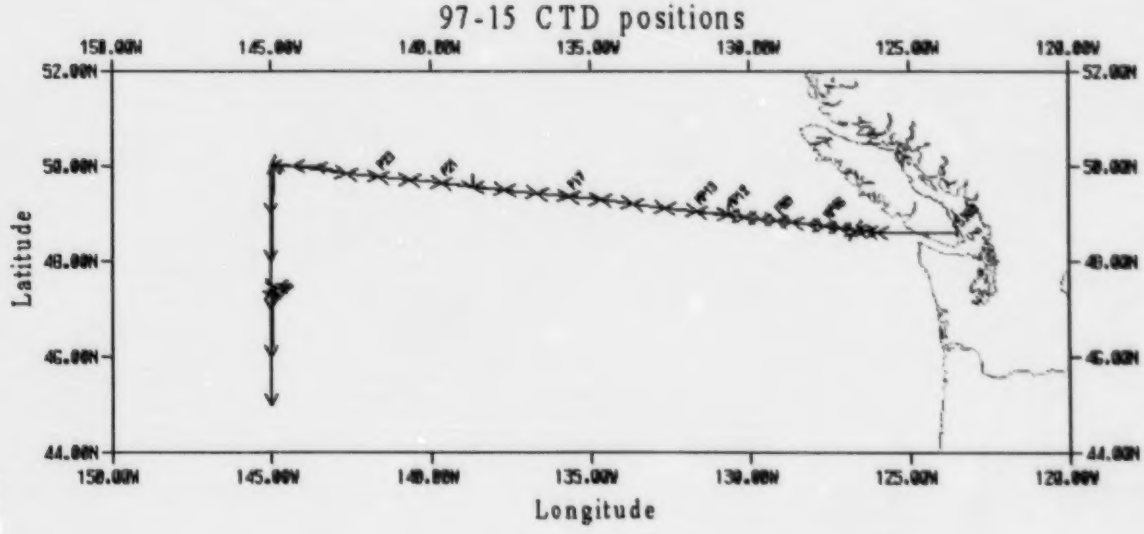
Longitude

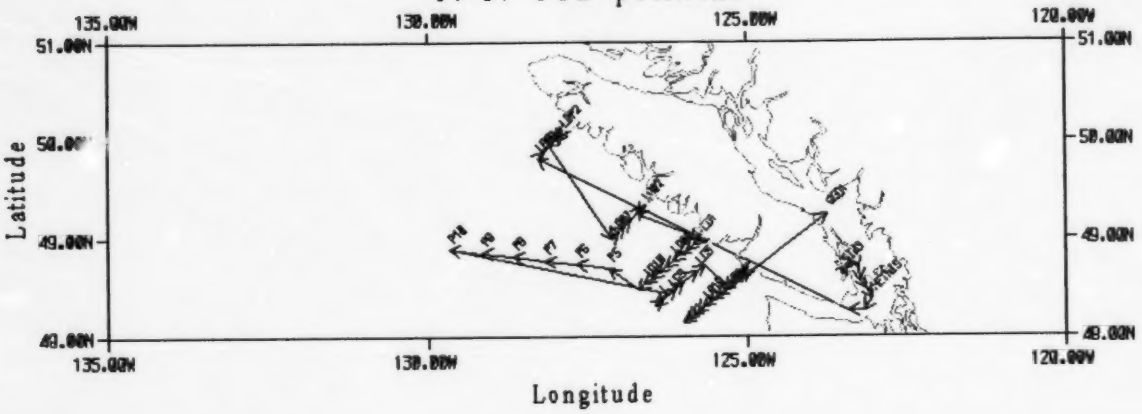

96-18 CTD positions
Latitude
Longitude


97-02 CTD positions
Latitude
Longitude

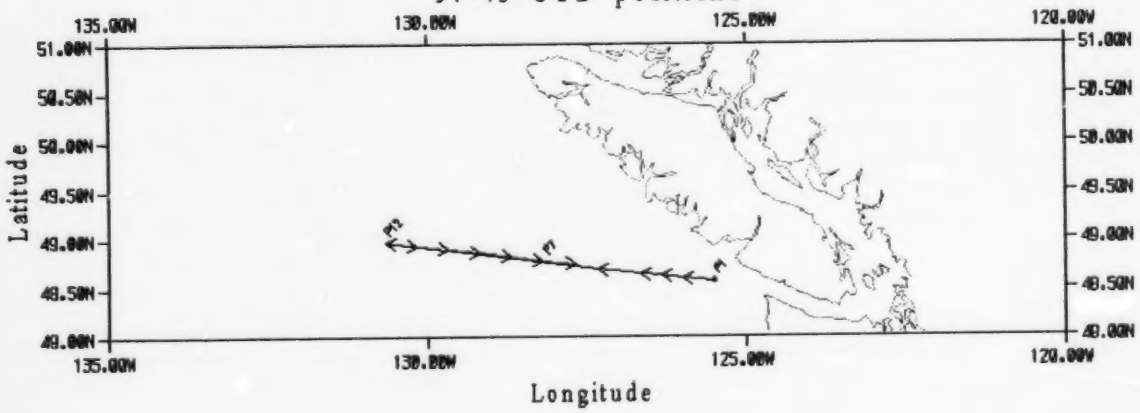

97-11 CTD positions
Latitude
Longitude


97-15 CTD positions
Latitude
Longitude

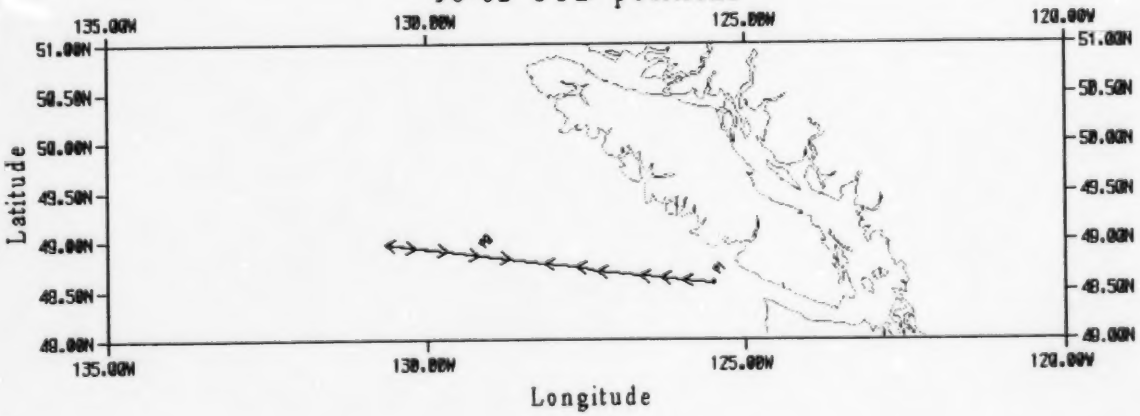
97-37 CTD positions

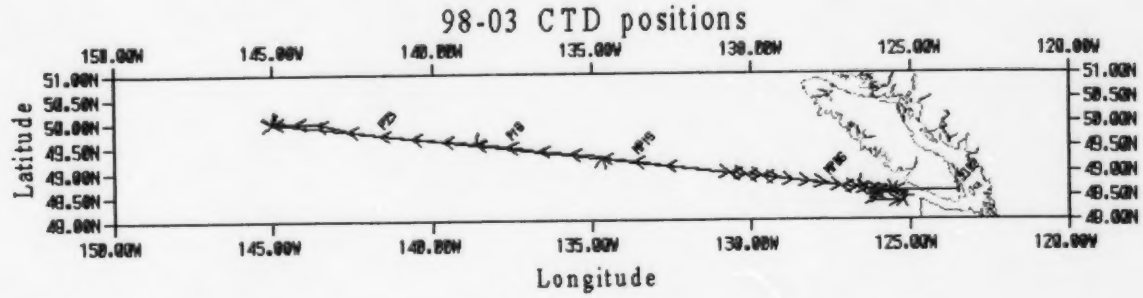


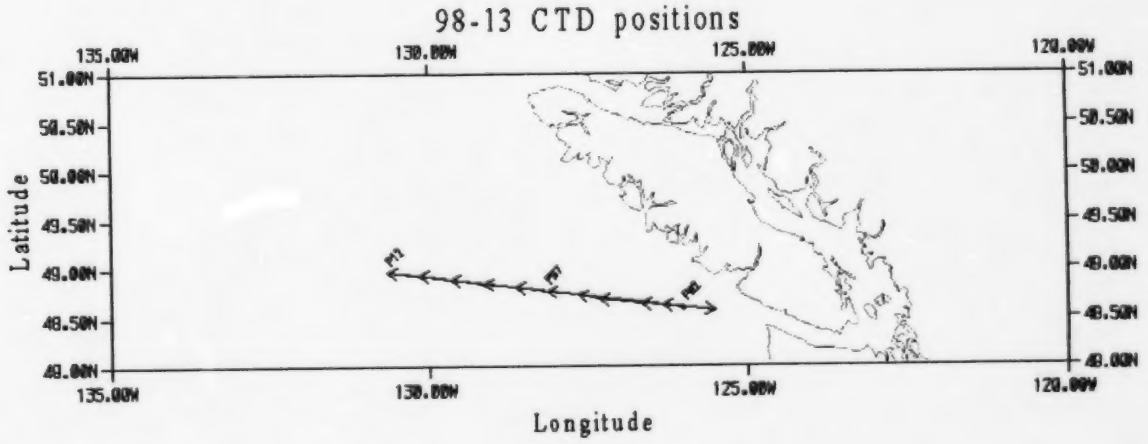
97-45 CTD positions

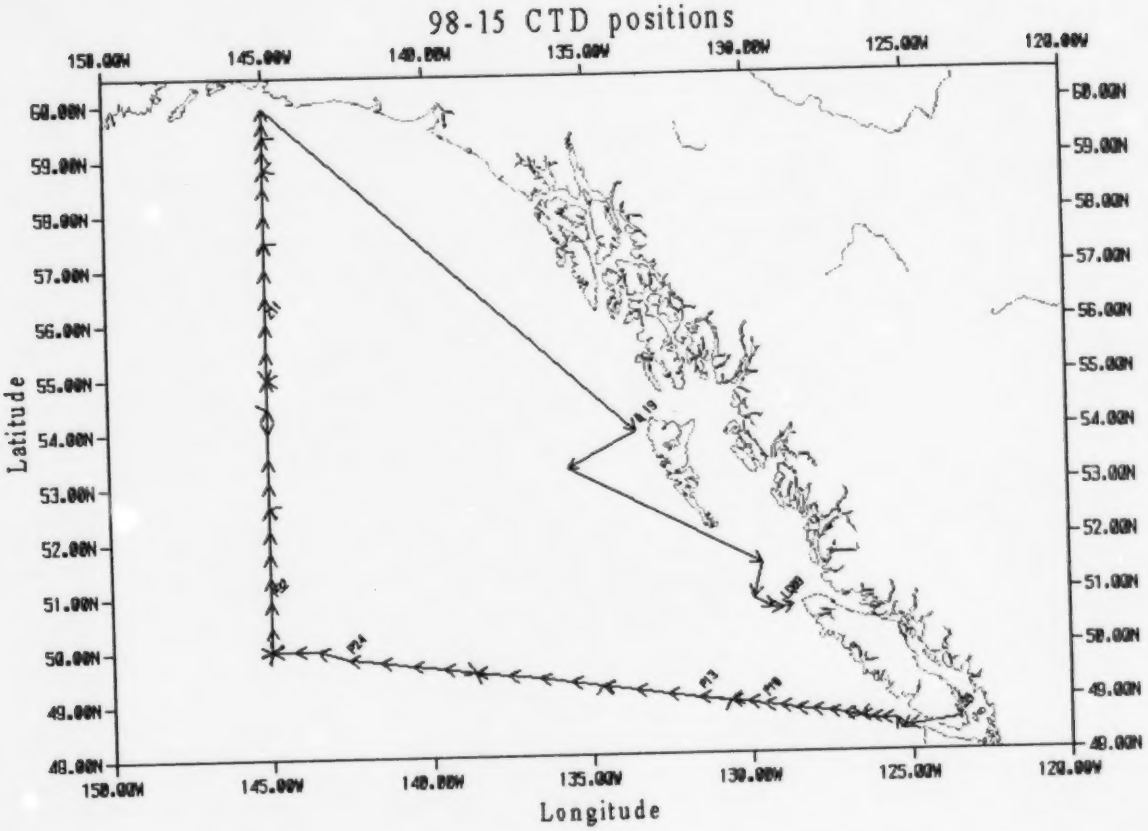


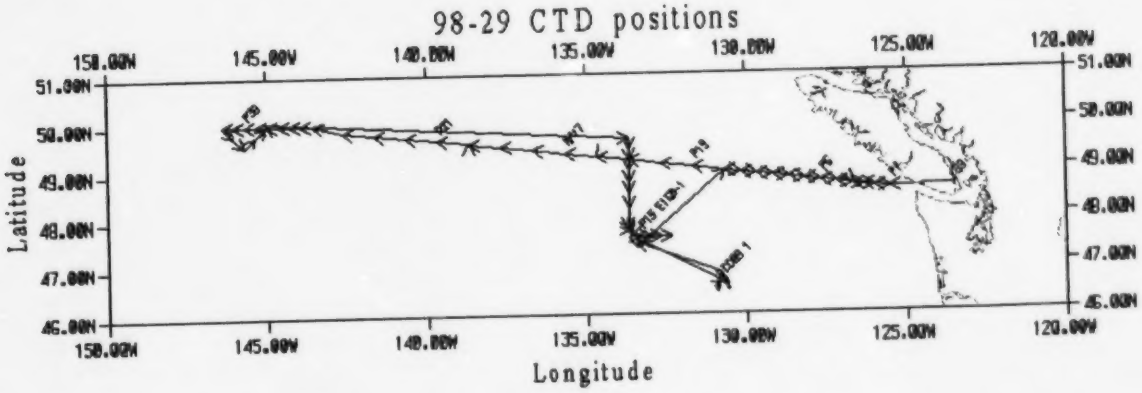
98-02 CTD positions

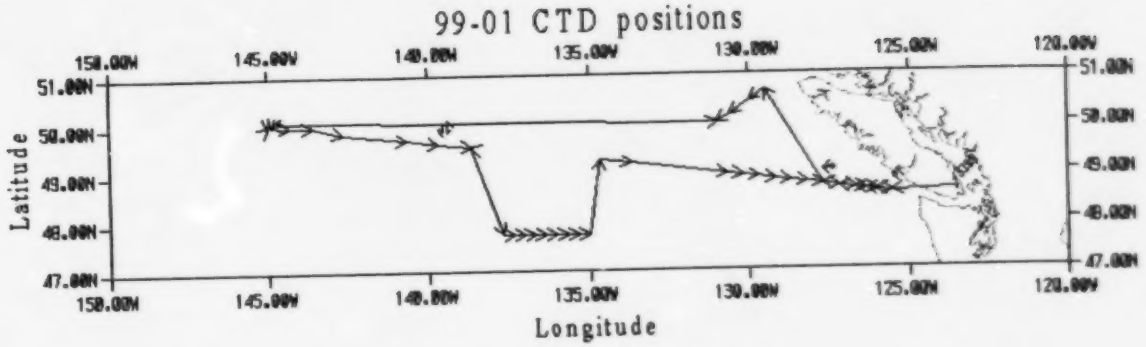


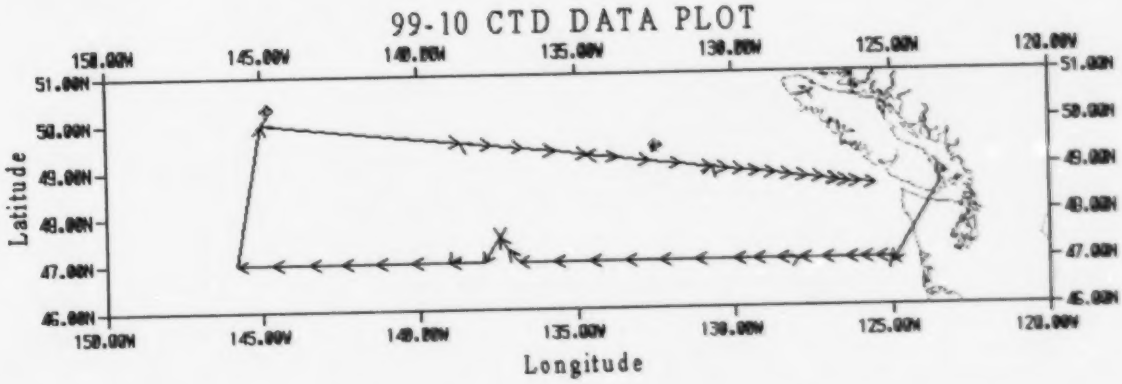

98-03 CTD positions
150.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
51.00N
50.50N
50.00N
49.50N
49.00N
48.50N
48.00N
Latitude
Longitude


98-13 CTD positions
135.00W
130.00W
125.00W
120.00W
51.00N
50.50N
50.00N
49.50N
49.00N
48.50N
48.00N
Latitude
Longitude


98-15 CTD positions
Latitude
Longitude
158.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
60.00N
59.00N
58.00N
57.00N
56.00N
55.00N
54.00N
53.00N
52.00N
51.00N
50.00N
49.00N
48.00N


98-29 CTD positions
Latitude
Longitude
158.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
51.00N
50.00N
49.00N
48.00N
47.00N
46.00N


99-01 CTD positions
150.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
51.00N
50.00N
49.00N
48.00N
47.00N
Latitude
Longitude


99-10 CTD DATA PLOT
150.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
51.00N
50.00N
49.00N
48.00N
47.00N
46.00N
Latitude
Longitude

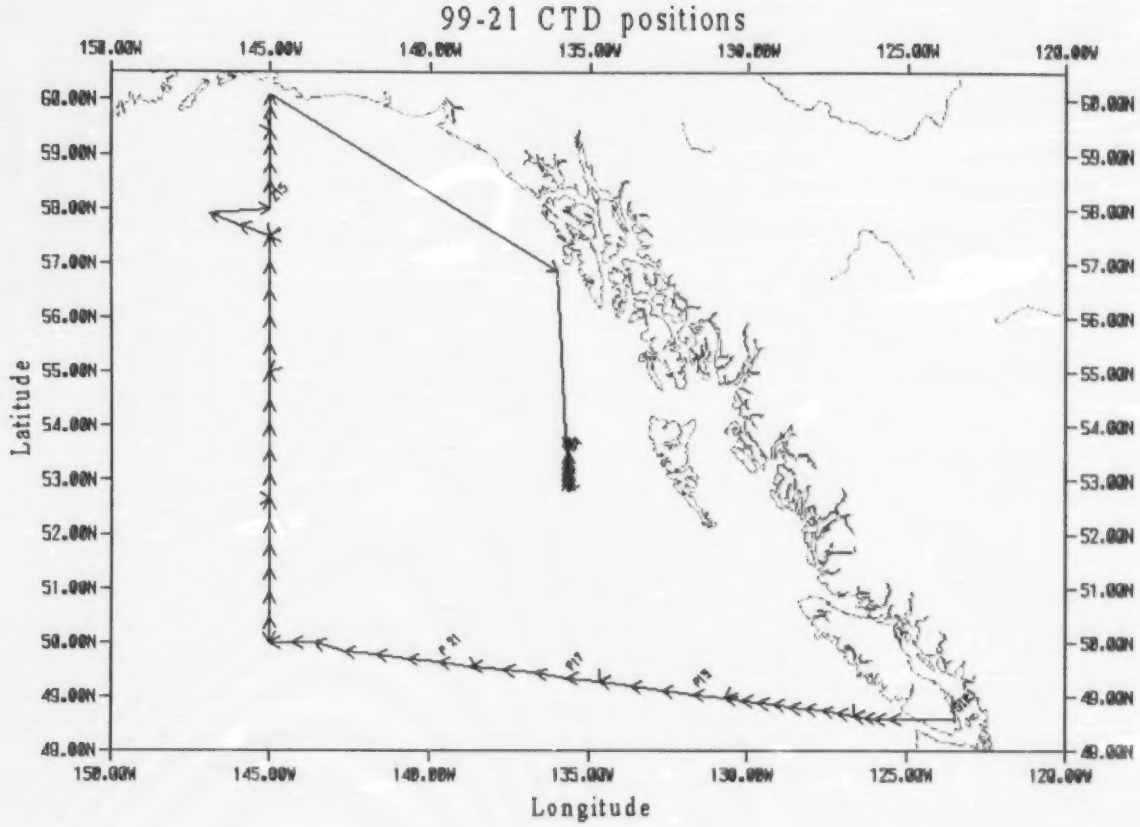
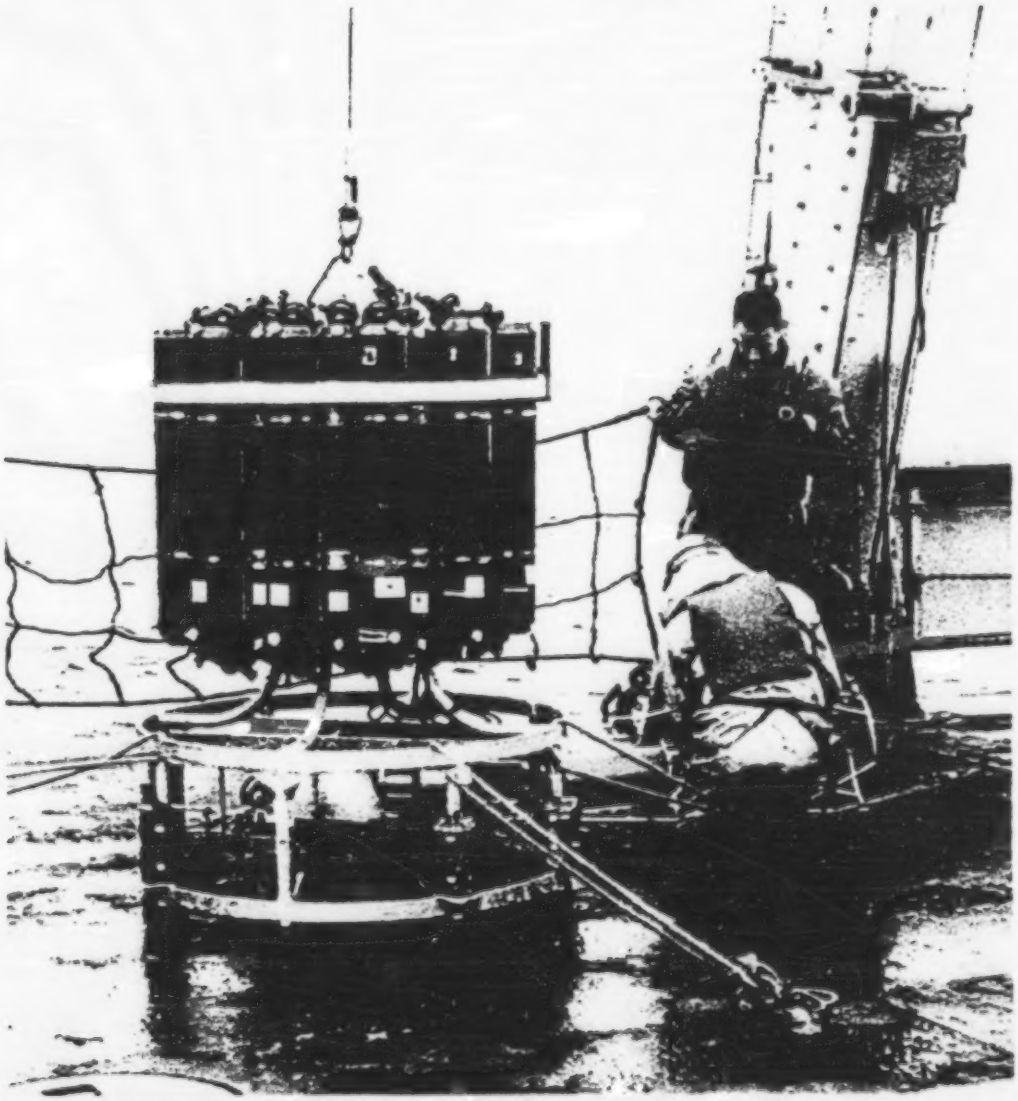
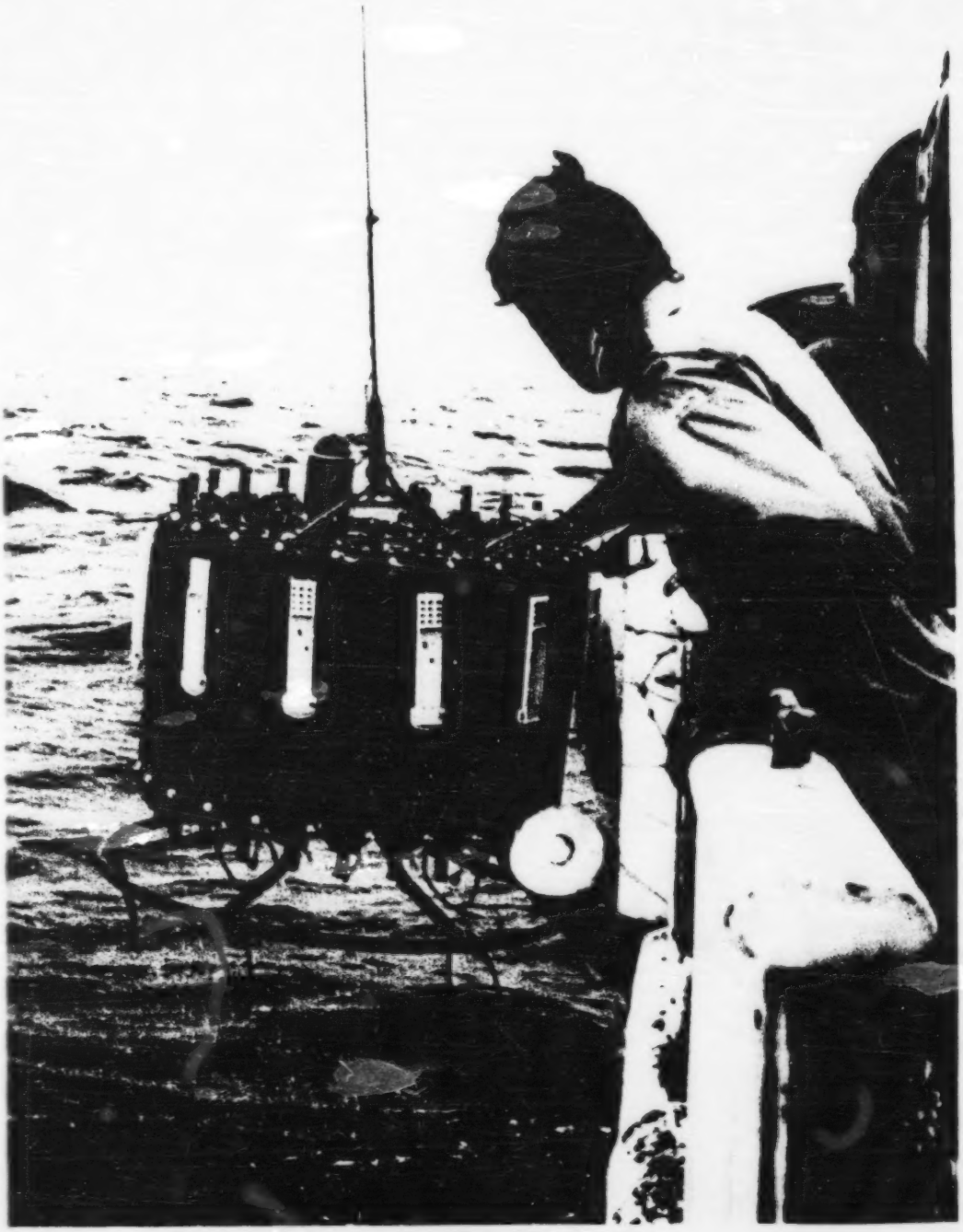

99-21 CTD positions
150.00W
145.00W
140.00W
135.00W
130.00W
125.00W
120.00W
60.00N
59.00N
58.00N
57.00N
56.00N
55.00N
54.00N
53.00N
52.00N
51.00N
50.00N
49.00N
48.00N
Latitude
Longitude
P25
P21
P17
P13
P9

Figure 1. IOS Rosette



IOS Rosette on deck of J.P. Tully

Figure 2. General Oceanics Rosette



General Oceanics Rosette
showing 10 litre sampling bottles

Figure 3. Heave Compensator mounted on CCGS Tully A-frame

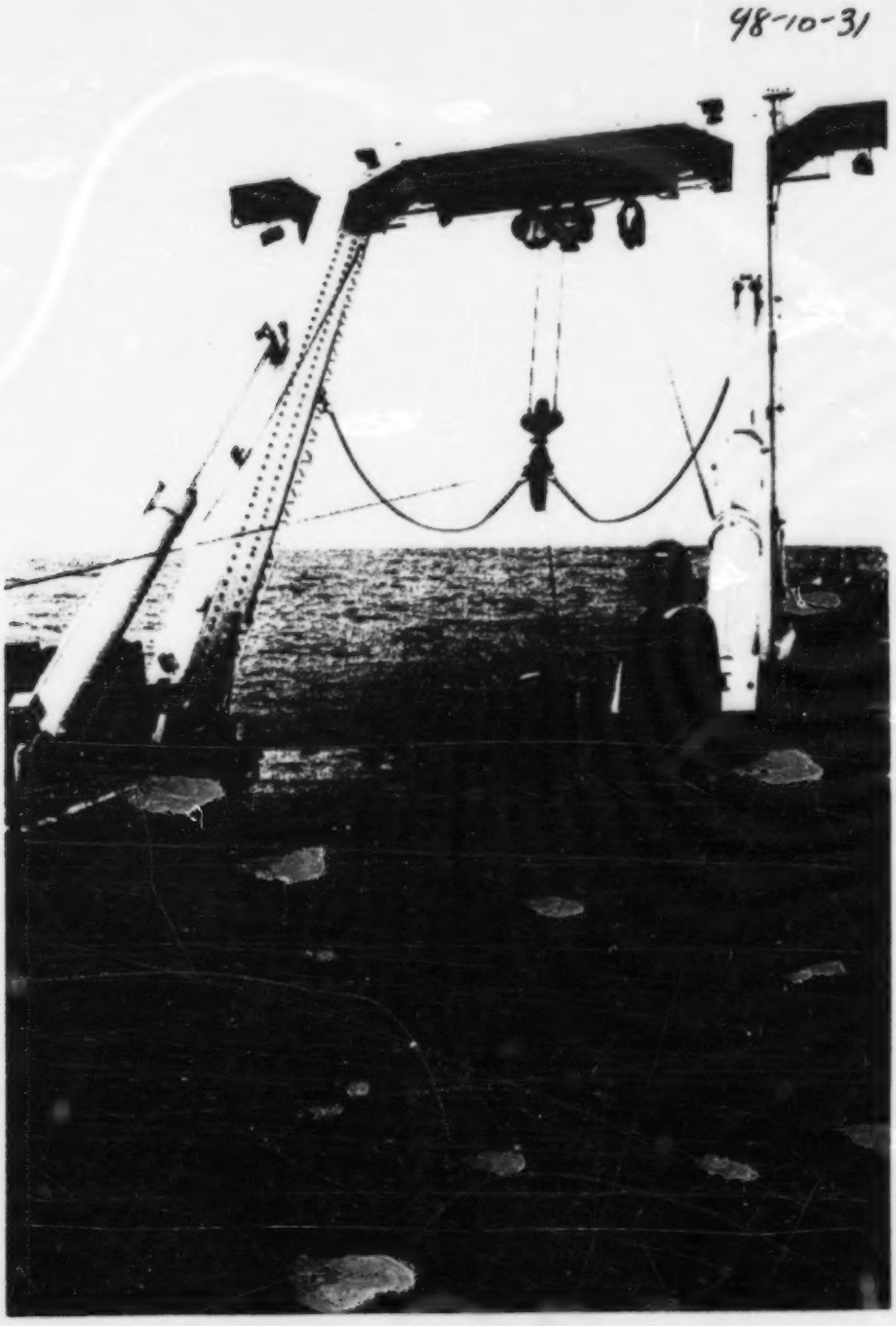


Figure 4. CSS Parizeau

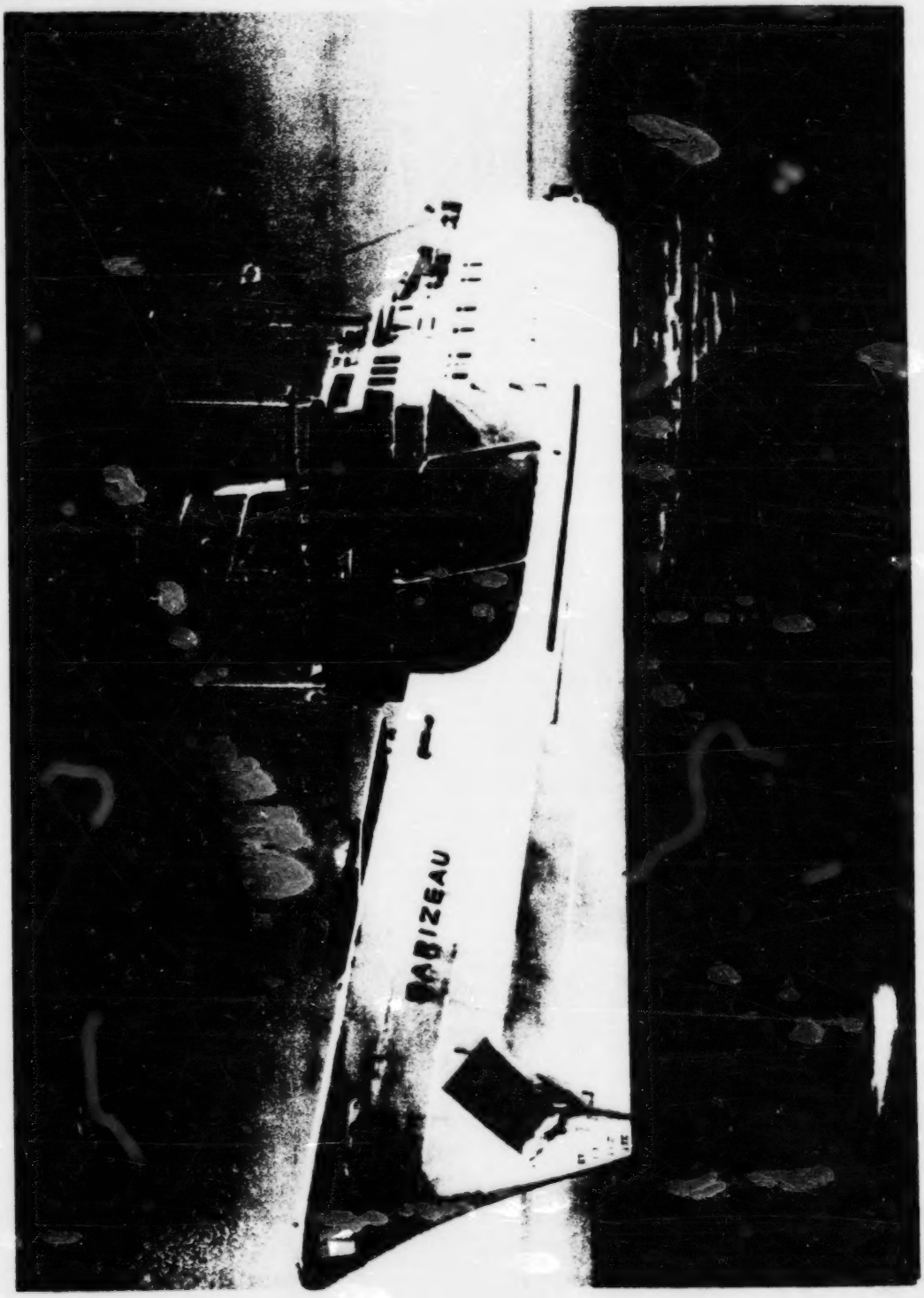


Figure 5. CCGS J.P. Tully

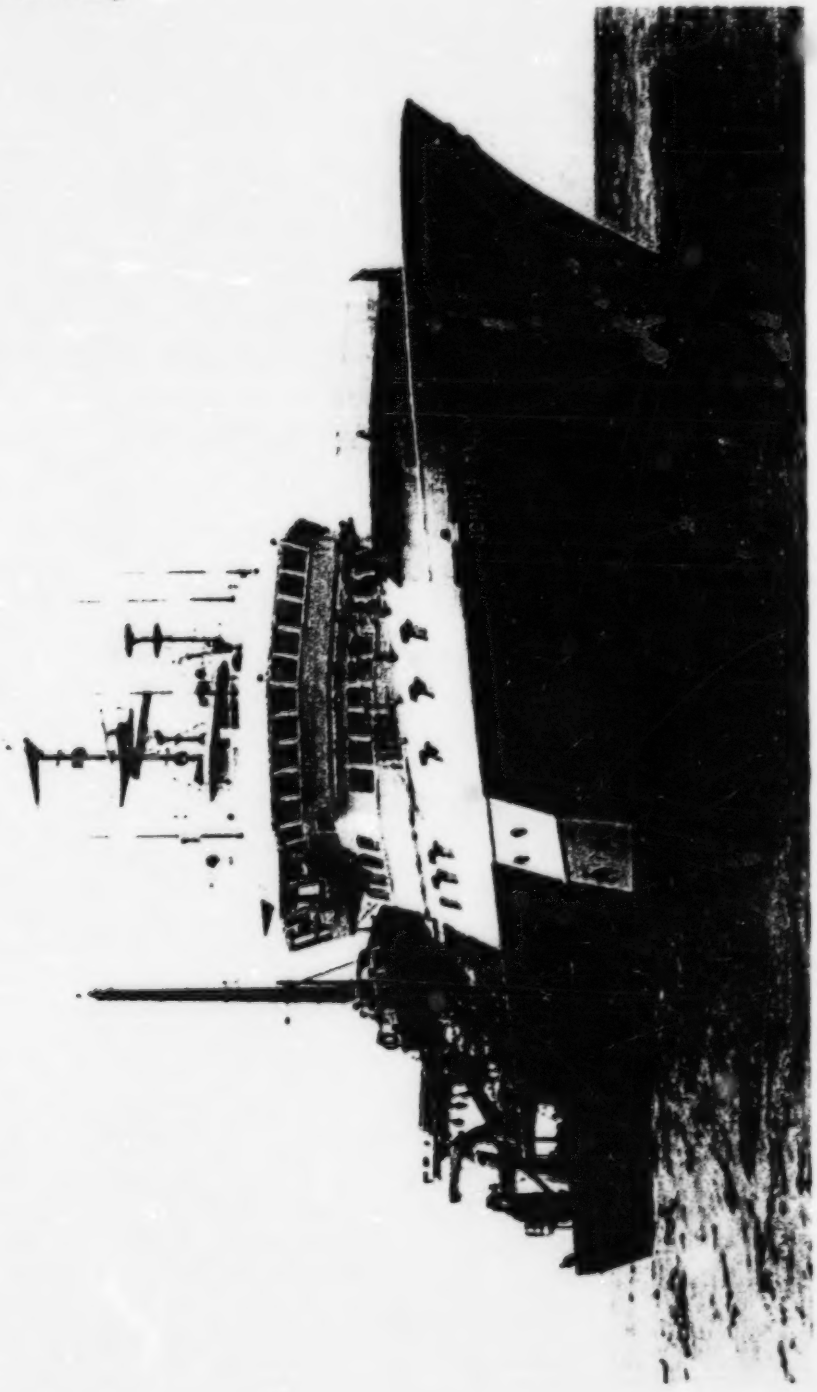


Figure 6. CNAV Endeavour